Iterative two-stage approach to estimate sources and their interactions

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#Tu-P68: Iterative two-stage approach to estimate sources and their interactions (iSDR)

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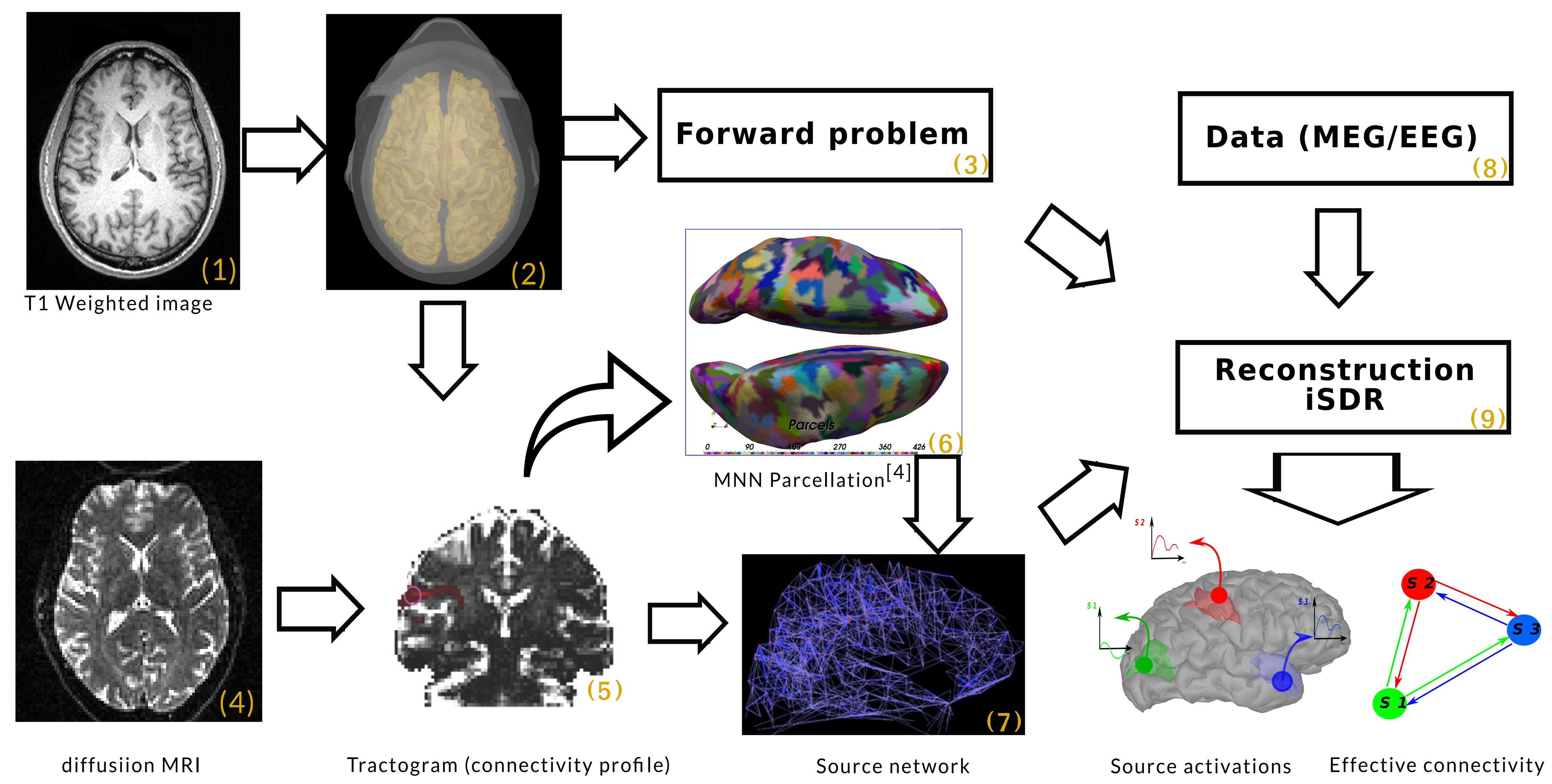
Abstract: Non-iterative two-stage approaches have been used to estimate source interactions. They first reconstruct sources and then compute the MAR model for the localized sources. They showed good results when working in high signal-to-noise ratio (SNR) settings, but fail in detecting the true interactions when working in low SNR. Our framework is based on two steps. First, we estimate sources activations for a given MAR model. Then, we estimate the MAR model. We repeat the two steps until a stopping criterion is achieved.

1 FRAMEWORK



- N: Number of sensors, P: Number of sources/patches
- p: Order of MAR model, A_v: Vec($[A_1; A_2; ..; A_p]$)
- $G \in \mathbb{R}^{N\times P}$: Lead field matrix
- $M_{p\to T} \in \mathbb{R}^{N\times(T-p+1)}$: MEG/EEG measurement
- $S_{1\to T-1} \in \mathbb{R}^{P\times(T-1)}$: Sources' activities
- S_v^*: Vec$(S_{1\to T-1})$, S_v: Vec$(S_{p\to T})$, M_v: Vec$(M_{p\to T})$
- $J \in \mathbb{R}^{P(T-p)\times pP^2}$: $\begin{pmatrix} \mathrm{diag}(S_1^T) & \mathrm{diag}(S_1^T) & \cdots & \mathrm{diag}(S_p^T) \\ \mathrm{diag}(S_2^T) & \mathrm{diag}(S_3^T) & \cdots & \mathrm{diag}(S_{p+1}^T) \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{diag}(S_{T-p-1}^T) & \mathrm{diag}(S_{T-p}^T) & \cdots & \mathrm{diag}(S_{T-1}^T) \end{pmatrix}$
- $G_d \in \mathbb{R}^{N(T-p)\times P(T-1)}$: $\begin{pmatrix} GA_1 & GA_2 & \cdots & GA_p & 0 & \cdots & 0 \\ 0 & GA_1 & \cdots & GA_{p-1} & GA_p & \cdots & 0 \\ \vdots & \vdots & \ddots & \ddots & \ddots & \ddots & \vdots \\ 0 & 0 & \cdots & \cdots & \cdots & \cdots & GA_p \end{pmatrix}$

S-STEP

$$U(S_{1\to T-1}) = \|M_v - G_d S_v^*\|_2^2 + \lambda \|S_{1\to T-1}\|_{21} \qquad (1)$$

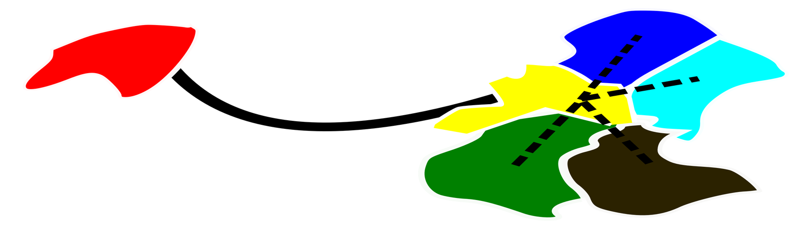
A-STEP

$$L(A_v) = \|S_v - J A_v\|_2^2 \qquad (2)$$

Eq (1) is an extension to MxNE[2] in which G is replaced by G_d (a matrix that changes at each iteration)

2 HYPOTHESIS

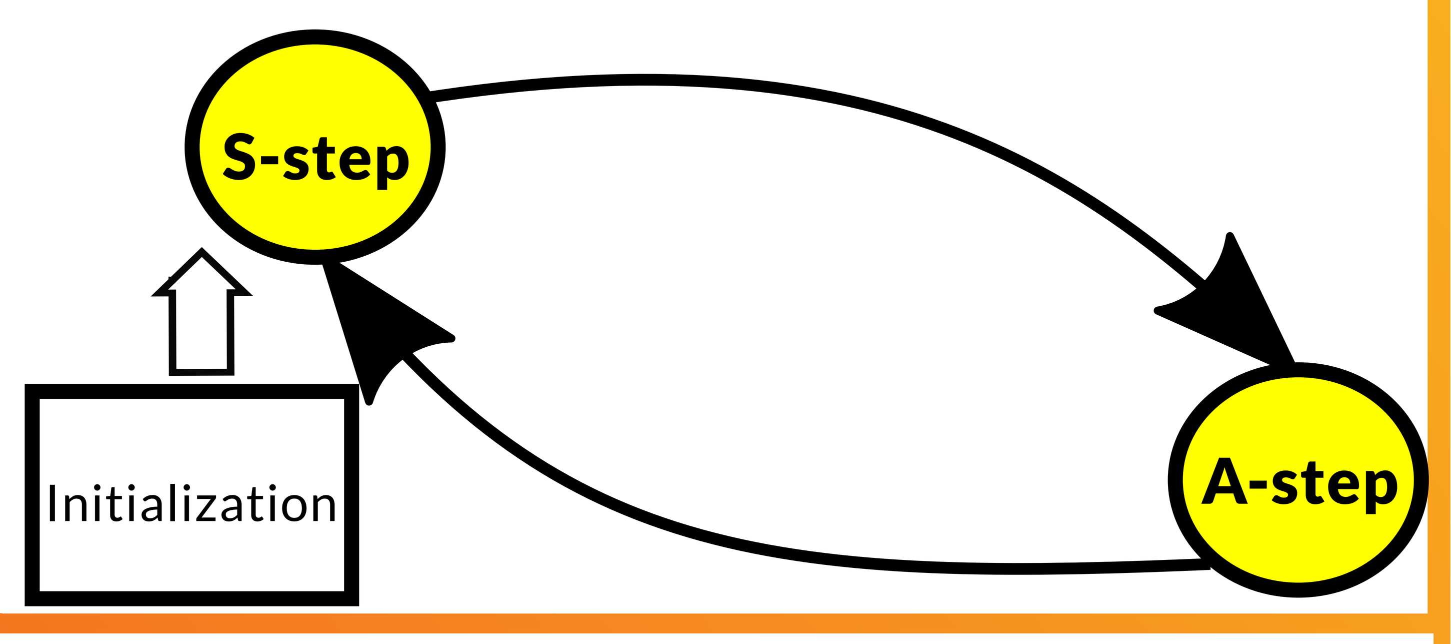
- Source activity depends on the activity of sources that are anatomically connected :
  - Detectable from dMRI (solid line)
  - Neighboring regions (dashed lines)



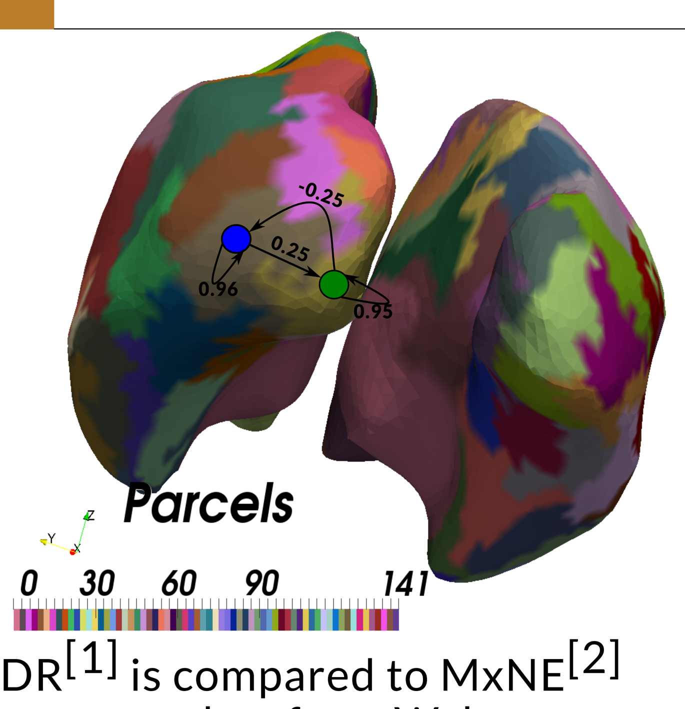
- Sources' dynamics follow a multi-variate autoregressive model of order p whose matrix entries are constant in a time window T.

$$S_t = \sum_{i=1}^{p} A_i S_{t-i} + \omega_t \qquad \omega_t \text{ Noise in the source space}$$

3 iterative Source and Dynamics Reconstruction (iSDR)

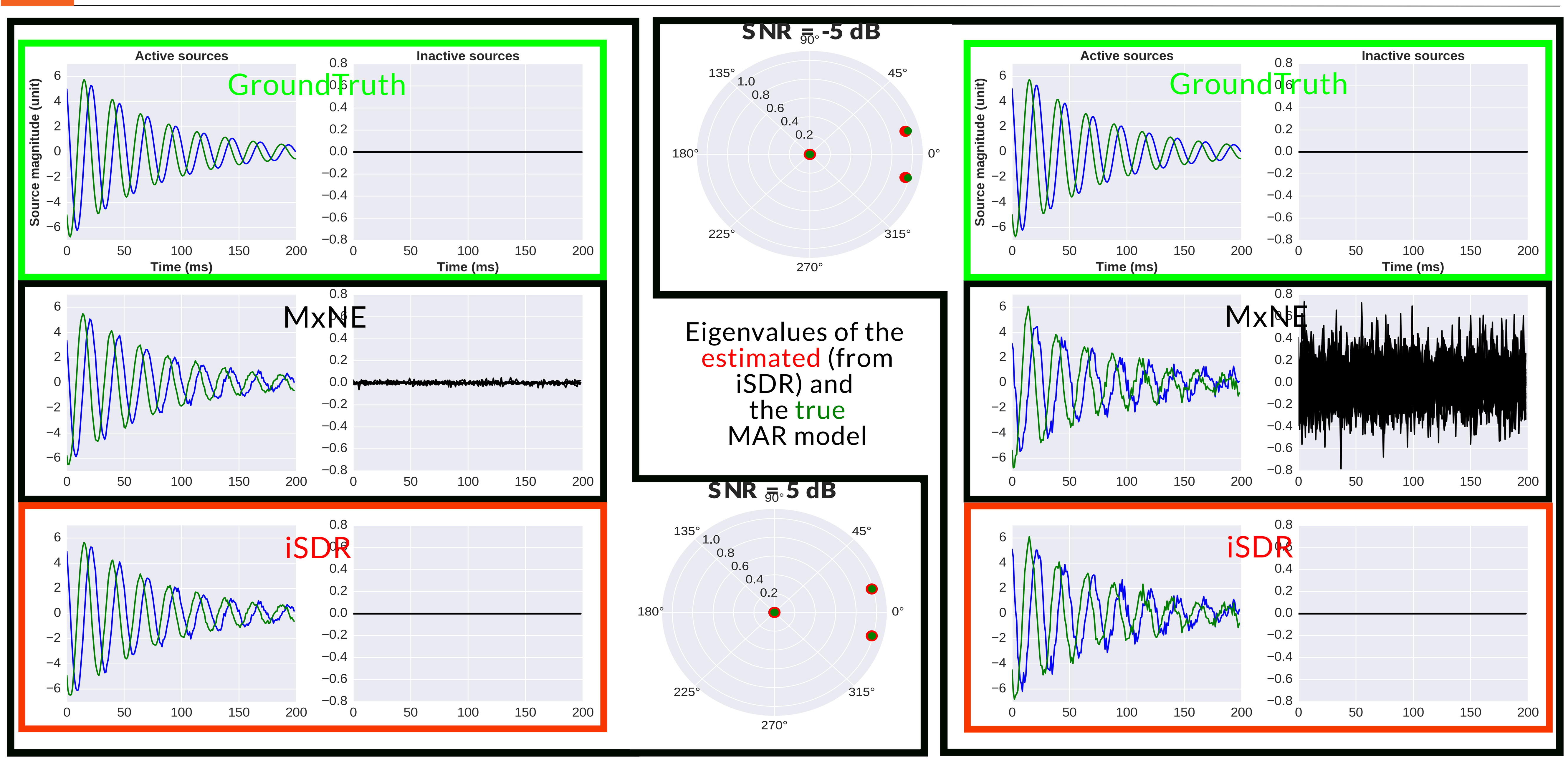


4 SYNTHETIC DATA



- -iSDR[1] is compared to MxNE[2]
- -Data was taken from Wakeman et al.[3]
- -Cortical regions where obtained using MNN parcellation[4]
- -MAR model of order 1 and with two non-zero eigenvalues of A: 0.93±0.24j

5 RESULTS



6 CONCLUSIONS

iSDR improved the MxNE and could detect true activations and functional interactions.

A source that is detected to be inactive in one of the iterations can not be reactivated in this framework (Eq (2)).

The number of time samples, T, must be greater than the maximum number of connections per source multiplied by p.

The order of the MAR model should be investigated.

References [1] B. Belaoucha et al., "Multivariate Autoregressive Model Constrained by Anatomical Connectivity to Reconstruct Focal Sources," 38th Annual International Conference of the IEEE EMBC, 2016. [2] A. Gramfort et al.,"Mixed-norm estimates for the M/EEG inverse problem using accelerated gradient methods," Physics in Medicine and Biology, vol.57, no.7, pp.1937-1961, 2012. [3] D. G. Wakeman et al., "A multi-subject, multi-model human neuroimaging dataset," Scientific Data, 2015. [4] B. Belaoucha et al., "Cortical Surface Parcellation via dMRI Using Mutual Nearest Neighbor Condition," IEEE 13th International Symposium on Biomedical Imaging (ISBI), pp. 903-906, 2016.

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